# JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2017

## Service of Hydrometeorology and Active Influence on Atmospheric Phenomena REPUBLIC OF ARMENIA

## 1. Summary of highlights

Service on Hydrometeorology and Active Influence on Atmospheric Phenomena of Armenia largely uses hydrometeorological products, e.g. synoptic charts and NWP maps from different Global Producing Centres (GPC) to produce weather forecasts for Armenia.. Armstatehydromet makes full operational use of all the ECMWF meteorological products MRF_EUROPA,WEATHER CENTRALE, which are available freely over the Internet for operational weather forecasting and objective analysis using actual observation information. Twice a day charts from 00 and 12 GMT starting time are available in Armhydromet.

Implementation of WRF and COSMO models is on-going, but still the results are not satisfactory, however works are carried out to achieve accuracy. The forecasting computation technology using the non-hydrostatic hydrodynamic model WRF was developed recently. Currently the model is operating on a daily basis.Particularly:
1.1.conducted experimental and operational exploitation of hydrostatic mesoscale model COSMO-ARM 14, mesh 14x14 km..

1.2. Continued research and operational exploitation of non-hydrostatic mesoscale model WRF-ARW_ARM. Are used 3 domains with grids 18x18,6h6,2x2km.

Tested physical parameterization schemes for WRF-ARW model with the ensemble (16 ensemble members).

Use of an operational technology using a new version of the regional atmospheric model WRF (horizontal resolution 50x50 km, 30 σ-levels) developed in the Hydrometeorological Centre of Armenia for the south region is being continued. The list of the model output products is increased. Equipment in use

**2. Facility in use:**

**WRF**
IIAP Cluster
6 nodes of
Model: MSI X2-108-A4M Intel Quad Core Xeon E5420 2.5 GHz
Memory: 8GB
Storage: 250 GB
Network between nodes: Gigabit Ethernet
6 nodes x 2 cpus per node X 4 cores per cpus = **48 cores**

**COSMO**
CPU-Intel Xeon Dual Core 2.66 Ghz 633MHz FSB
RAM -4GB
VIDEO RAM-16MB
HDD-1500GB
OS-Red Hat Linux Asp 4

Some experiments are carried out for air temperature, precipitation, wind forecasting and verification of results for mountain and foothill areas of the South regions (Synik, Vajoc Dzor,Ararat..), with a resolution of 2 km.

The system derives GFS data in GRIB2 format from NCEP server (forecasts starting at 00 and 12 UTC), pre-processing programs WPS (geogrid, ungrib, metgrid) is applied. Forecasting results are presented in NetCDF automated calculation. Visualization and meteograms are performed in NCL system.

The non-hydrostatic WRF-ARW / NCAR mesoscale model (version 3) is tested using NCEP model results for the initial state and boundary conditions.

The resolution of nested domain changed to 2km, which allows to predict convective processes. Several physics experiments have been planned and conducted for different physics schemes (Microphysics, Surface layer physics, Land surface model, Boundary layer, Long and short wave radiation) in order to find the best combination and improve current results, the works are ongoing. For verification of model results MET package will be used.

## 3. Used Data and Products from GST and other Communication Systems

### 3.1. Observational data (number of telegrams 8 daily):

- SYNOP, TEMP
- Gridded products in GRIB/GRIB2 code from:
- DWD global model (GME)
- NCEP model

## 4. Forecasting system

### 4.1. Time Schedule and Forecasting Period

Conventional methods of weather forecasting are applied in Armhydromet based on analysis of actual information using baric fields forecast, which is being received from the Word Meteorological Centre (Washington), European Centre for Medium Range Weather Forecasts (Reading), and Moscow Centre.

Every day meteorological, sea, hydrological and agrometeorological forecasts are made up. Regularly the week, decade weather forecasts are issued for all the regions of Armenia One of the main tasks of Armenia is to make forecasts of the dangerous and natural phenomena, reports of the weather changes and distribute to customs and user.
Armhydromats activities in medium range forecasting are based on ECMWF operational model. This means twice a day with 00 and 12 GMT starting time are available to Armhydromet. Short range NWP modeling is based on mesoscale WRF model.

### 4.2 Medium range forecasting system (4-10 days)

Armstatehydromet makes full operational use of all the ECMWF meteorological products MRF_EUROPA,WEATHER CENTRALE, which are available freely over the Internet for operational mesoscale weather forecasting and objective analysis.

#### 4.2.1 Data assimilation, objective analysis and initialization

4.2.1.1 In operational mode:

The global system of data assimilation system and of the objective analysis of the Hydrometcentre of Armenia .

Cycle assimilation system – 4 times a day, observations for: 00, 06, 12, 18 UTC;

Method of analysis: 2-dimentional interpolation for 1-level characteristics and 3-dimentional optimal interpolation for geopotential and wind fields.

Products – sea level pressure, surface air temperature, temperature of underlying surface, surface air humidity and wind velocity, total octant cloudiness, snow cover depth, sea surface temperature, geopotential heights at isobaric levels, wind velocity, temperature and air humidity on standard isobaric levels.

Coverage – the Globe.

Horizontal resolution – 2.5x2.5°, 1.25x1.25°.

Levels – 10, 30, 50,70, 100, 150, 200, 250, 300, 400, 500, 700, 850, 925, 1000 hPa, sea level pressure, topography for calculation of surface characteristics.

4.2.1.2 Research performed in this field

NA

#### 4.2.2 Model

4.2.2.1 In operation

10-day deterministic forecasts are available at Armhydromet. Charts from the Word Metrological Centre (Washington), European Centre for Medium Range Weather Forecasts (Reading), and Moscow Centre are used for making up forecasts. Some of the products are downloaded as images and displayed on internal website.

mean sea level pressure analysis and forecast

2 m temperature analysis and forecast
10 m wind analysis and forecast
temperature analysis and forecast on
100/925/850/700/500/400/300/250/200/150mb pressure levels
geopotential height analysis and forecast on
100/925/850/700/500/400/300/250/200/150mb pressure levels
specific humidity analysis and forecast on
100/925/850/700/500/400/300/250/200/150mb pressure levels
wind components analysis and forecast on
100/925/850/700/500/400/300/250/200/150mb pressure levels
sea surface temperature
sea ice cover

4.2.2.2 Research performed in this field
[Summary of research and development efforts in the area]

Our research has shown that modelling of winds and low-level jets (LLJs) in Armenia by the WRF model ishighly sensitive to the choice of planetary boundary-layer (PBL) parametrization scheme and initial conditions at high spatial resolution (3 km). To this end, the WRF simulations initialized by GFS and newly released European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-5 reanalysis data have been performed using nine different PBL schemes. The both datasets have comparable spatial resolution (28-30 km). However, those use different data assimilation techniques, general circulation models etc. Therefore, differences in large-scale circulation and soil conditions may lead to high sensitivities in the WRF simulations (Gevorgyan, 2018). Among the nine tested planetary boundary layer (PBL) parameterization schemes the MYJ, QNSE, and TEMF PBL schemes showed greater skill in simulation of near-surface valley winds over Yerevan, while the other PBL schemes tend to significantly underestimate the strength of valley winds, with the BouLac PBL scheme being the worst performer. Most of PBL schemes simulate well-defined LLJs in Yerevan associated with evening valley winds. The simulated jet cores are mostly located between 150 and 250 m above ground with magnitudes varying from 12 to 21 m $s^{-1}$. However, the intensity of the observed nocturnal LLJ in Yerevan (located at 110 m above ground) is strongly underestimated by most of the WRF runs while the Shin and Hong and YSU PBL schemes simulate nocturnal LLJs higher than the observed LLJ. The WRF runs initiated with newly released European Centre for Medium-Range Weather Forecasts ERA-5 data set showed improved simulation of near-surface winds and nighttime potential temperatures in Yerevan relative to those forced by the Global Forecast System fields.
Another topic of research performed was modelling of of cold-air pools in Ararat Valley, Armenia leading to extraordinary cold-waves (Melkonyan *et al.*, 2017). 24-hour simulations derived from WRF model were used to assess the WRF model's capabilities to reproduce strong cold-air pool (CAP) over the Ararat Valley observed on 20 December 2016 when minimum temperatures decreased up to -20 $^0$C and lower. The WRF model was applied with spatial resolutions of 9 and 3 km and 65 vertical levels based on Global Forecast System model's (GFS) initial and boundary conditions at 0.25x0.25 deg. resolution. It was shown that MYJ PBL scheme outperforms the MYJ scheme in simulating the spatial pattern of CAP over the Ararat Valley, while the YSU scheme simulates significantly colder temperatures over entire Armenia with negative temperature biases lower than -7 $^0$C at most of the stations.

### 4.2.3 Operationally available Numerical Weather Prediction Products

[brief description of variables which are outputs from the model integration]

### 4.2.4 Operational techniques for application of NWP products *(MOS, PPM, KF, Expert Systems, etc..)*

4.2.4.1 In operation
NWP products are used to pre-fill site forecast information in selected points. The information is later over-viewed by duty forecaster.

4.2.4.2 Research performed in this field
[Summary of research and development efforts in the area]

### 4.2.5 Ensemble Prediction System (EPS)

4.2.5.1 In operation
NA *(Describe also: time range, number of members and number of models used: their resolution, number of levels, main physics used, perturbation of physics, post-processing: calculation of indices, clustering)*

4.2.5.2 Research performed in this field
[Summary of research and development efforts in the area]

4.2.5.3 Operationally available EPS Products

EPS products from ECMWF are available at Armhydromet. The ECMWF EPSgrams are used including forecasts up to 10 days issued twice daily for the Total Cloud cover, Total Precipitation, Wind Speed, Temperature.

### 4.3 Short-range forecasting system (0-72 hrs)

Charts from the Word Metrological Centre (Washington), European Centre for Medium Range Weather Forecasts (Reading), and Moscow Centre are used for making up forecasts. For drawing of atmospheric fronts are analyzed initial GRID data base, SYNOP, TEMP and results of SYNOP and TEMP objective analyses, and satellite information.

The new forecasting computation technology using the non-hydrostatic hydrodynamic model WRF is developed. Currently the runs of the model are conducted daily.

#### 4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation
[information on Data assimilation (if any), objective analysis and initialization,] (Indicate boundary conditions used)

Boundary conditions for the forecasting computation technology using the non-hydrostatic hydrodynamic model WRF are provided by GFS.

The regular two times in a day automated calculation from 36 to 168-hour forecasts using the WRF mesoscale model is realized at the computational complex XEON- E5420 with resolution 18 and 6 km. Also forecasting meteorology: air temperature, precipitation, wind, mountain and foothill areas of the South regions of Armenia(Synik, Vajoc Dzor,Ararat..), with a resolution of 2 km.

The system skims GFS data in GRIB2 format from NCEP server (forecasts starting at 00 and 12 UTC), starting pre-processing programs WPS (geogrid, ungrib, metgrid) with these data, starting WRF ARW model . Forecasting results are presented in NetCDF format with meteorological fields visualization and development of meteograms is performed in NCL system. Starting time is 00 and 12 UTC.

Objective analysis of the current atmospheric conditions in the region is carried out. The analyzed parameters include: geopotential, wind speed components and temperature at the 11 standard isobaric surfaces (1000, 925, 850, 700,500, 400, 300, 250, 200, 150, and 100 hPa) and fields of humidity at 6 levels (1000, 925, 850, 700,500, and 400 hPa). Horizontal resolution of the output fields is 18 km. As the first approximation fields, the results of GFS forecasts with resolution 1x1$^{o}$ are used.

The information received from the ground stations (48) includes real-time data on air temperature, relative humidity, wind speed and direction, pressure.

4.3.1.2 Research performed in this field
DWD provides the analysis and forecasts of GME on all 60 model layers and seven soil layers at a horizontal resolution of 30 km four times per day, namely, up to 78 hours with hourly intervals, based on the initial states for 00 and 12 UTC. These data are distributed by DWD via internet between 02:40 to 03:30 UTC for 00 UTC and between 14:40 to 15:30 UTC for 12 UTC.

#### 4.3.2 Model

4.3.2.1 In operation

4.3.3 Operationally available NWP products

Sea level pressure, surface air temperature, surface air humidity and wind velocity, total cloudiness in octant, snow cover height, geopotential heights of isobaric surfaces, wind velocity, temperature and air humidity on standard isobaric surfaces.

#### 4.3.4 Operational techniques for application of NWP products

4.3.4.1 In operation

[brief description of automated (formalized) procedures in use for interpretation of NWP ouput]
*(MOS, PPM, KF, Expert Systems, etc..)*
MOS and an application for mixed human automated forecast.

4.3.4.2 Research performed in this field

[Summary of research and development efforts in the area]
MOS -an application for bias correction for the temperature, humidity and wind speed for station forecasts is developed.

#### 4.3.5 Ensemble Prediction System

4.3.5.1 In operation

**NA** *(Describe also: time range, number of members and number of models used: their domain, resolution, number of levels, main physics used, for post-processing: calculation of indices, clustering)*

ECMWF is used as the only source of information.

4.3.5.2 Research performed in this field

NA

4.3.5.3 Operationally available EPS Products

[brief description of variables which are outputs from the EPS

### 4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

#### 4.4.1 Nowcasting system

4.4.1.1 In operation

4.4.1.2 Research performed in this field

[Summary of research and development efforts in the area]

#### 4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.1 In operation

Actual synoptic charts and satellite information are used for producing very short range forecasts

4.4.2.2 Research performed in this field

[Summary of research and development efforts in the area]

### 4.5 Specialized numerical predictions

[Specialized NP on sea waves, storm surge, sea ice, marine pollution transport and weathering, tropical cyclones, air pollution transport and dispersion, solar ultraviolet (UV) radiation, air quality forecasting, smoke, sand and dust, etc.]

NA

#### 4.5.1 Assimilation of specific data, analysis and initialization (where applicable)

4.5.1.1 In operation

NA

4.5.1.2 Research performed in this field

#### 4.5.2 Specific Models (as appropriate related to 4.5)

4.5.2.1 In operation

NA

4.5.2.2 Research performed in this field

A dynamical-statistical model on the dispersion of air pollution depending of weather and topography from the main industrial enterprises in several cities of Armenia is under development.

### 4.5.3 Specific products operationally available

NA

#### 4.5.4 Operational techniques for application of specialized numerical prediction products *(MOS, PPM, KF, Expert Systems, etc..)* (as appropriate related to 4.5)

4.5.4.1 In operation

"[brief description of automated (formalized) procedures in use for interpretation of specialized NP output]"

4.5.4.2 Research performed in this field

[Summary of research and development efforts in the area]

#### 4.5.5 Probabilistic predictions (where applicable)

4.5.5.1 In operation

"[Number of runs, initial state perturbation method etc.]" *(Describe also: time range, number of members and number of models used: their resolution, main physics used etc.)*

NA

4.5.5.2 Research performed in this field

NA

4.5.5.3 Operationally available probabilistic prediction products

"[brief description of variables which are outputs from probabilistic prediction techniques]"

## 4.6 Extended range forecasts (ERF) *(10 days to 30 days)*

**NA**

#### 4.6.1 Models

4.6.1.1 In operation

[information on Models and Ensemble System in operational use, as appropriate related to 4.6]

4.6.1.2 Research performed in this field

[Summary of research and development efforts in the area]

### 4.6.2 Operationally available NWP model and EPS ERF **products**

[brief description of variables which are outputs from the model integration]

## 4.7 Long range forecasts (LRF) *(30 days up to two years)*

4.7.1 In operation

Consensus based Seasonal Outlook from SEECOF is used for producing national seasonal outlooks

4.7.2 Research performed in this field

Implementation of Climate Predictability Tool (IRI) has been initiated recently. Several predictors (SST, NAO, ENSO) are being tested.

### 4.7.2 Operationally available EPS LRF products

[brief description of variables which are outputs from the model integration]

# 5. Verification of prognostic products

5.1 [annual verification summary to be inserted here]

The verification of short- and middle-range weather forecasts of general purpose is made according to manual on a weather service accepted in Армhydromet . This is not a computing method and calculations are manually made up. The average verification of our forecast is around 80-90%. As of WRF products verification we just making compare simulated meteorological fields with actual data .

## 5.2 Research performed in this field

[Summary of research and development efforts in the area]

Verification of daily precipitation forecasts in Armenia has been considered making use of ERA-Interim model output data. Verification of forecasted daily precipitation amounts is carried out over the period 1996 – 2010 using observed daily precipitation amounts of 30 meteorological stations of Armenia. Daily precipitation amounts possess high spatial-temporal variability in Armenia associated with complex orography. Verification results have shown that the mentioned variability of precipitation amounts is not represented appropriately by forecasted data. The latter is mainly because of relatively coarse resolution of used forecasted data (on $1.5x1.5^0$ grid).

## 6. Plans for the future *(next 4 years)*

### 6.1 Development of the GDPFS

**6.1.1** [major changes in the Operational DPFS which are expected in the next year]

**6.1.2** [major changes in the Operational DPFS which are envisaged within the next 4 years]

### 6.2 Planned research Activities in NWP, Nowcasting, Long-range Forecasting and Specialized Numerical Predictions

"[Summary of planned research and development efforts in NWP, Nowcasting, LRF and Specialized Numerical Predictions for the next 4 years]"

#### 6.2.1 Planned Research Activities in NWP

The physics experiments for WRF model started recently will continue during next year. Implementation of WRF 3D-VAR data assimilation system is planned for the next year.
Research should be done on simulating local strong severe weather events (convective rainfalls, hailstorms, strong wind gusts) over a mountain topography of Armenia through sensitivity experiments with the WRF various parametrization schemes and initial and lateral boundary conditions. Data assimilation is needed to be applied to further improve the simulation results (conventional, satellite and radar data assimilation). Updated versions of WRF model and WRFDA (version 4.0, 2018) should be tested to see the improvements in simulation results. The limitations in HPC resources is challenging issue for a progress in the research on modelling over Armenia.

#### **6.2.2** Planned Research Activities in Nowcasting

#### 6.2.3 Planned Research Activities in Long-range Forecasting

It is planned to continue works on the implementation of CPT using the outcomes of different GCMs.
The previously planned activities on the development of Long Range Forecasting system applying Multi-model Ensemble Prediction for Global dynamic models predictions from global producing centers (GPCs) and further Regional Downscaling using Regional Climate Models have started but not been fulfilled due to lack of human and technical capacities. Nevertheless this work is still of highest priority for the service.

#### 6.2.4 Planned Research Activities in Specialized Numerical Predictions

The development of a dynamical-statistical model on the dispersion of air pollution from large industrial enterprises will be continued and tested for certain locations.

## 7. References

[information on where more detailed descriptions of different components of the DPFS can be found]
*(Indicate related Internet Web sites also)*

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